International Centre for Indoor Environment and Energy
www.ie.dtu.dk

Department of Mechanical Engineering
Technical University of Denmark

International Centre for Indoor Environment and Energy

Staff

- Researchers (~ 10)
- Technical staff (~ 5)
- Ph.D. students (~ 20)
- Master students (~ 10)
- Visiting professors and post docs (~ 5)
- From ~ 10 countries

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Teaching

- Indoor climate
- Ventilation and climatic systems
- Heating and cooling systems
- Heat transmission
- Mould in buildings
- Man and the physical environment
- Experimental methods in fluid dynamics

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Budget

- STVF (Danish Research Council) 10 year grant
- Danish Technology Council
- EU research program
- Industrial contracts
- ASHRAE
- Industrial sponsors

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Research

- Health
- Comfort
- Productivity
- Air distribution techniques & technologies
- Energy efficency

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Activity Plan 2003 - 2007

- Desirable indoor environments
- Particles
- Chemical transformations
- Ventilation, damp buildings and health
- Airborne transmission of infectious agents

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Activity Plan 2003 - 2007

(Continued)

- Rethinking air handling
- Individually controlled environment
- Combined effects of thermal, acoustic and olfactory environment
- Control strategies

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Current Projects

(Continued)

- Indoor climate and productivity
- Learning in schools
- Advanced air distribution
- Individually controlled environment

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Current Projects

(Continued)

- Low humidity
- Aircraft cabin ventilation
- Pollution sources in buildings
- Air cleaning, filters, chemical reactions

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Current Projects

(Continued)

- Association between allergy/asthma and indoor air quality in homes (Sweden, Bulgaria & Denmark)
- Ventilation in dwellings - measurement and evaluation from the health and energy point of view
- The effect of phthalate esters on human health

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Current Projects

(Continued)

- Thermo-active building systems – Energy use and thermal environment (drifting temperature)
- Occupant responses in office buildings with moderately drifting temperatures

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Current Projects

(Continued)

- Indoor environment in museum storage rooms
- Removal of particles from the supply air of ventilation systems avoiding the formation of sensory pollution source
- Photocatalytic oxidation of acetone by UV-transperant photocatalytic reactor

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Current Projects

(Continued)

- Use of operative temperature for control
- People's behaviour regarding control of the indoor environment
- Comfort and Energy Optimal Control of Heating and Ventilation Systems
- Combined effects

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Current Projects

(Continued)

- Chilled beams
- Design strategies for airflow distribution in rooms with personalized and total volume ventilation
- Thermal plums generated by human body
- Airborne transmission of infectious agents

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The ALLHOME study
Indoor Environment in Homes and Health

K. Naydenov, J. Sundell, A. Melikov

Objectives

- To map the housing conditions regarding indoor environment in two representative urban areas of Bulgaria
- To explore the associations between housing condition and symptoms in airways, eyes, nose and skin in children age 2 to 7.

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Indoor Environment in Homes and Health

Method

- **Study population**
  - Bulgaria
  - two regions: Sofia (3 districts) and Burgas
  - all children- 2 and 3, 5 and 7 years of age
- **Structure**

ALLHOME-1

Cross-sectional study
Questionnaire
n=4479 children

→

ALLHOME-2

Case-control study
Technical and medical investigation
n=215 ch., 209 dwellings

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Indoor Environment in Homes and Health

Method - The ALLHOME 2 study

- Nested case-control study (medical and engineering measurements)
- Case and control children selected based on the ALLHOME-1 study
- December-March 2005
- Medical and engineering measurements:
  - Building inspection, 24h-CO2, RH, T; dust samples
  - Examination, Skin Prick Test (10 allergens), urine
- Collected data: 215 children (111 cases, 114 controls), 211 houses

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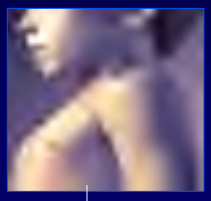
Indoor Environment in Homes and Health

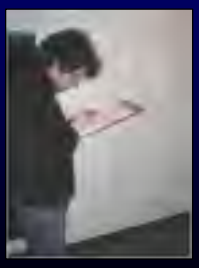
Method - The ALLHOME 2 study



Wheezing/ Asthma

Rhinitis/ Hey fever

Eczema



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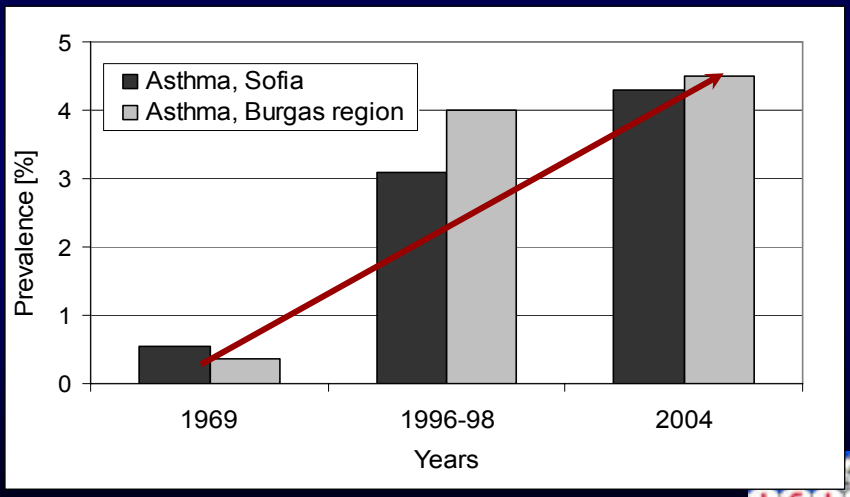
Indoor Environment in Homes and Health

Results: Health history 1969 - 2004



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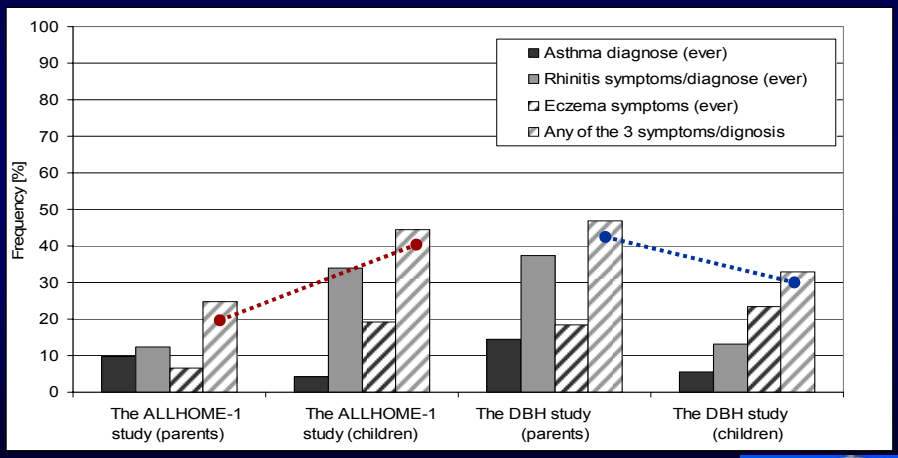
Indoor Environment in Homes and Health

Results: Children vs. Parents



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Indoor Environment in Homes and Health

Results: Dampness

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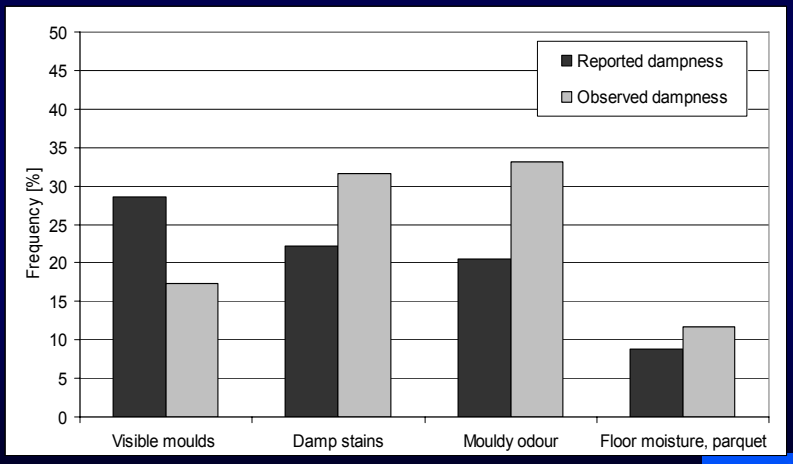
Indoor Environment in Homes and Health

Results: Dampness



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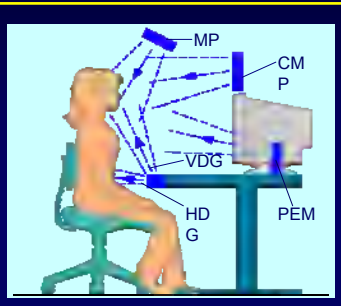
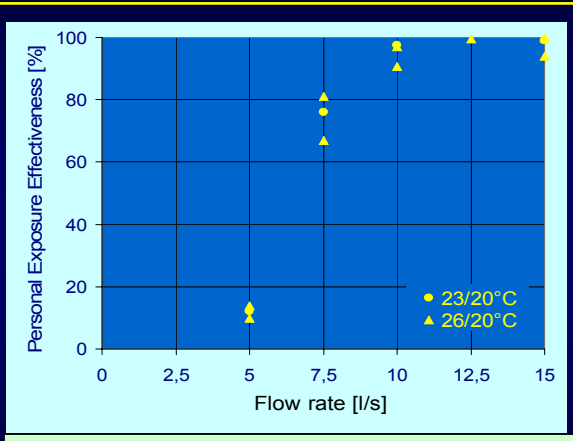
Personalized Ventilation

A. Melikov





Ventilation effectiveness: $V_{eff} = \frac{C_e}{C_i} \geq 50$

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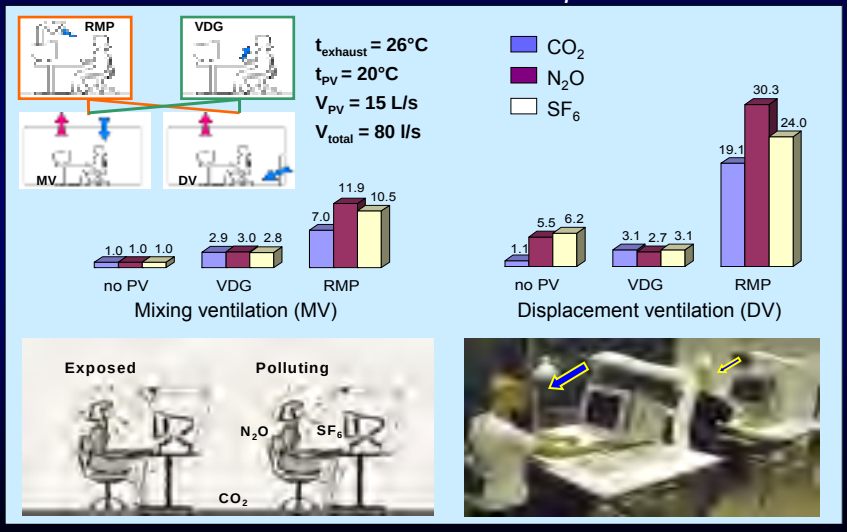
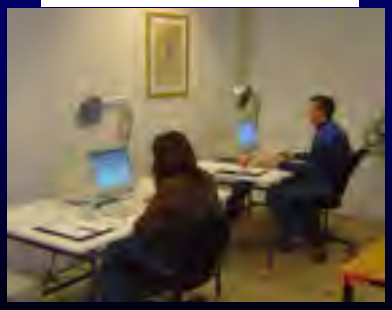
Personalized Ventilation

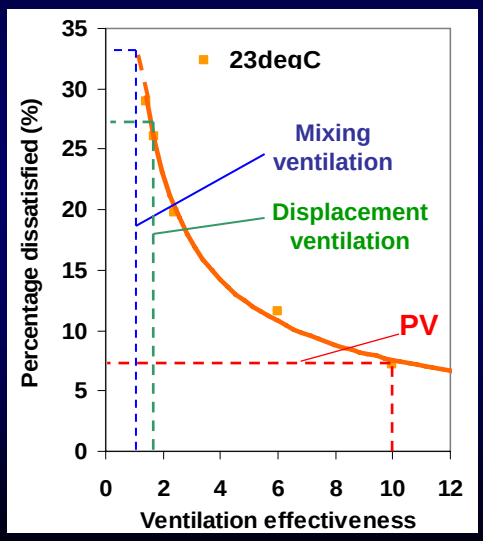
The results show how many times PV in conjunction with MV or DV decreased contaminants in inhaled air in comparison with MV alone



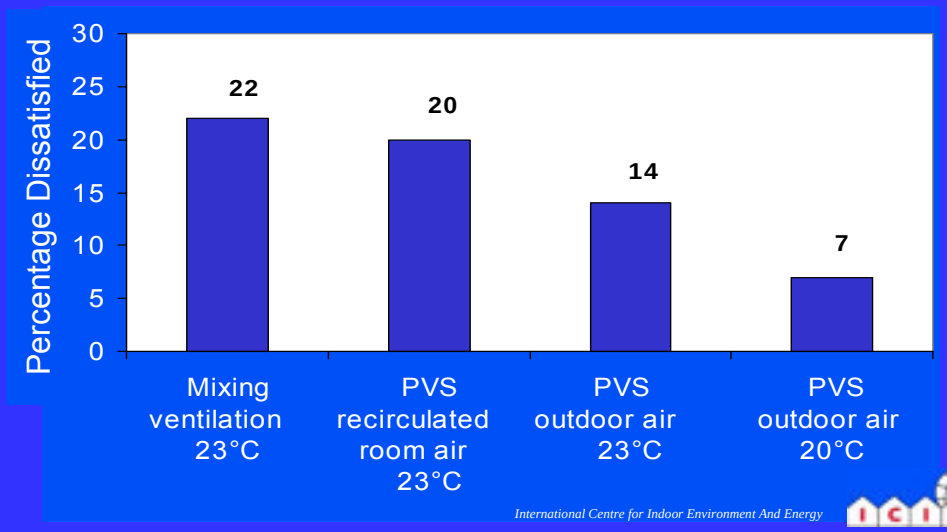
Personalized Ventilation

Ventilation effectiveness → PAQ?





Personalized Ventilation



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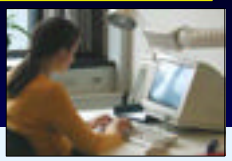
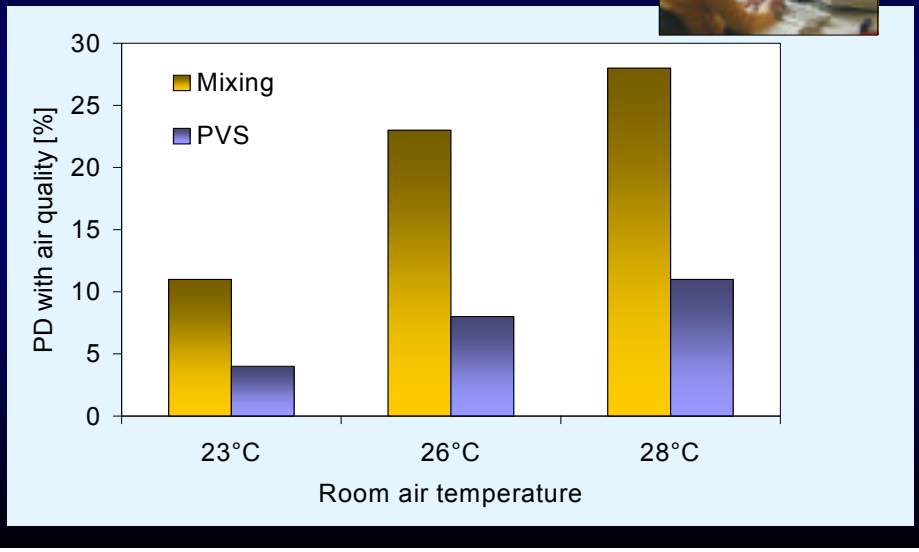
Personalized Ventilation

Human Response: PAQ

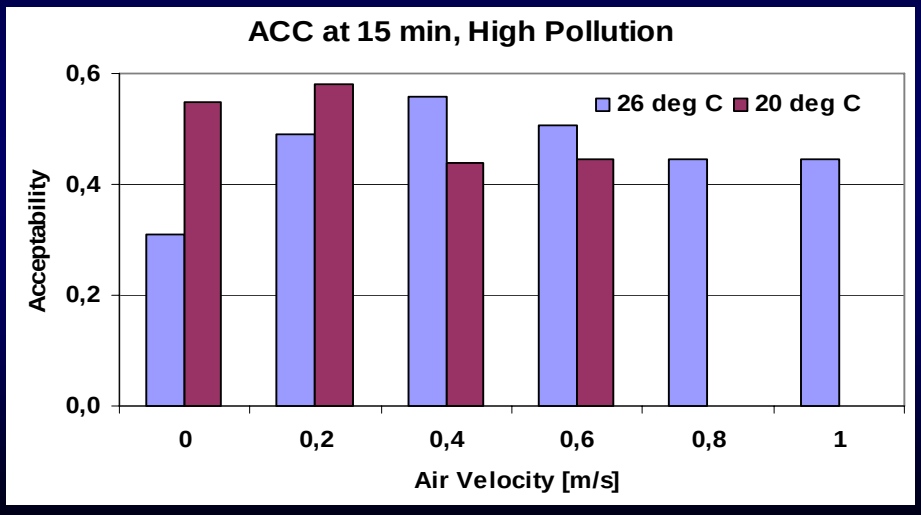
20 L/s/person, t_{PVS} = 23°C





Perceived Air Quality

Impact of Facial Velocity



Perceived Air Quality

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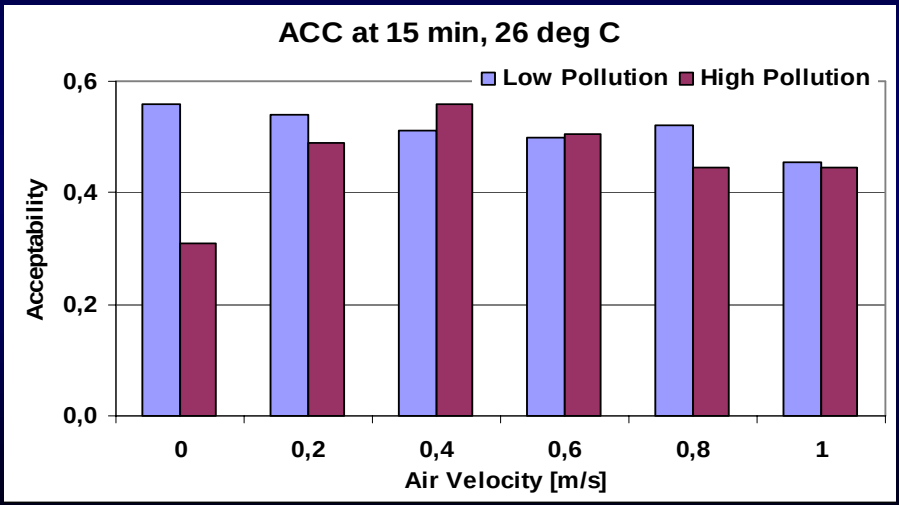
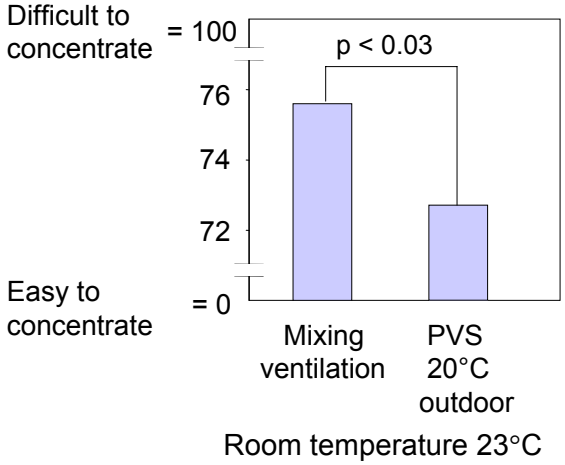
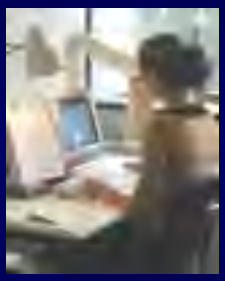


Personalized Ventilation

Human Response: SBS symptoms





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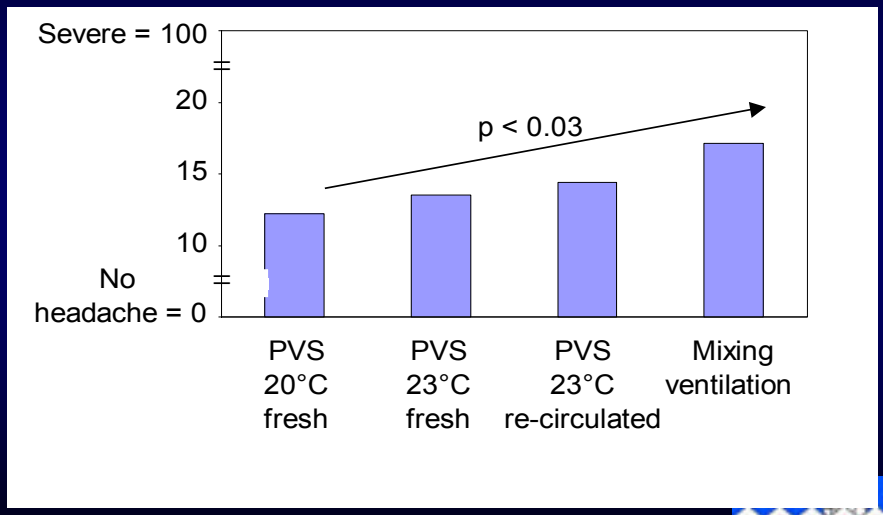
Personalized Ventilation

Human Response: SBS symptoms



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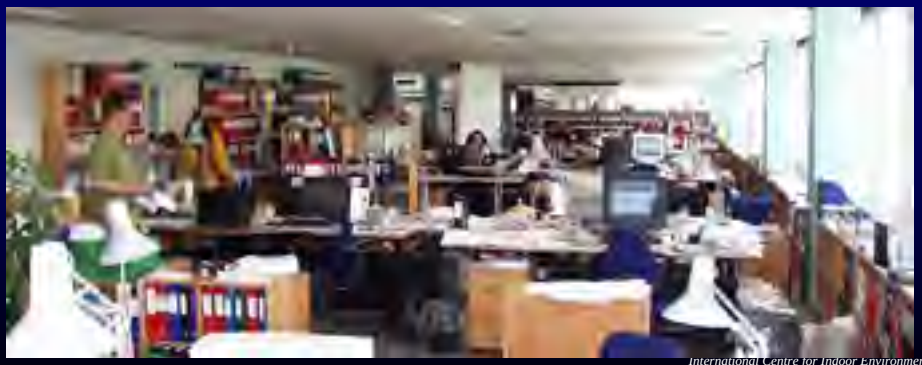
Personalized Ventilation

Occupant's activity

Occupied density (OD) - the ratio of the time an occupant stays at workplace with PV over the total time he/she stays in the room.

OD = 1 means that occupants stay at their workplaces and are exposed to personalized air all the time.



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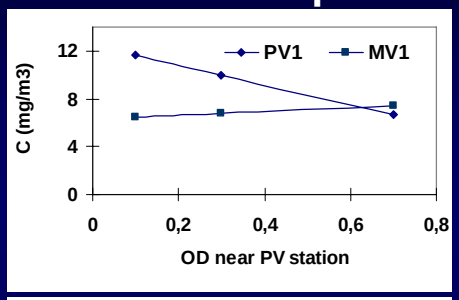
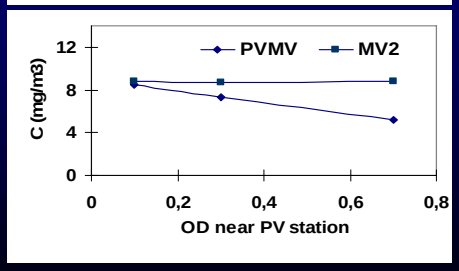
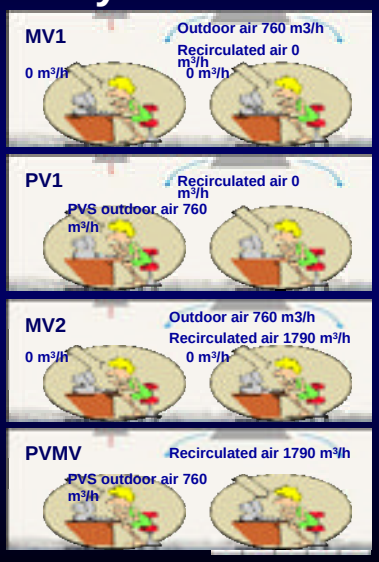
Personalized Ventilation

Occupant's activity



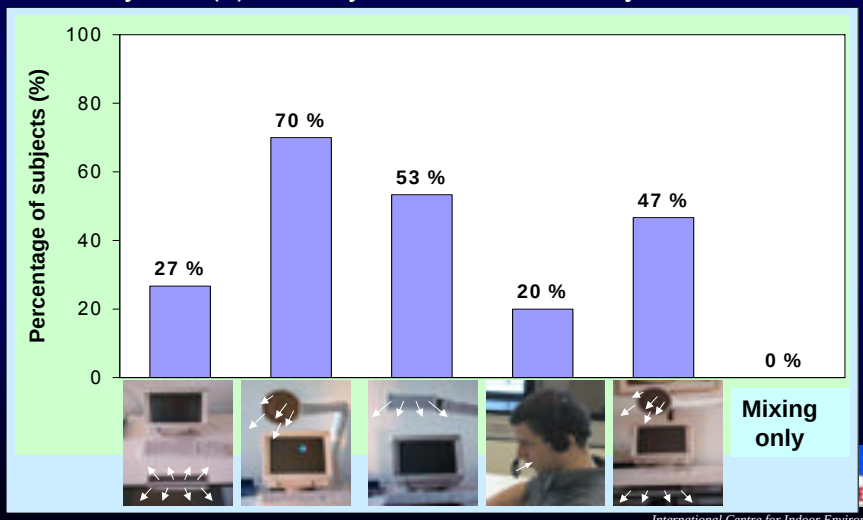




Personalized Ventilation

Subjective evaluation

Which system(s) would you like to have on your desk?

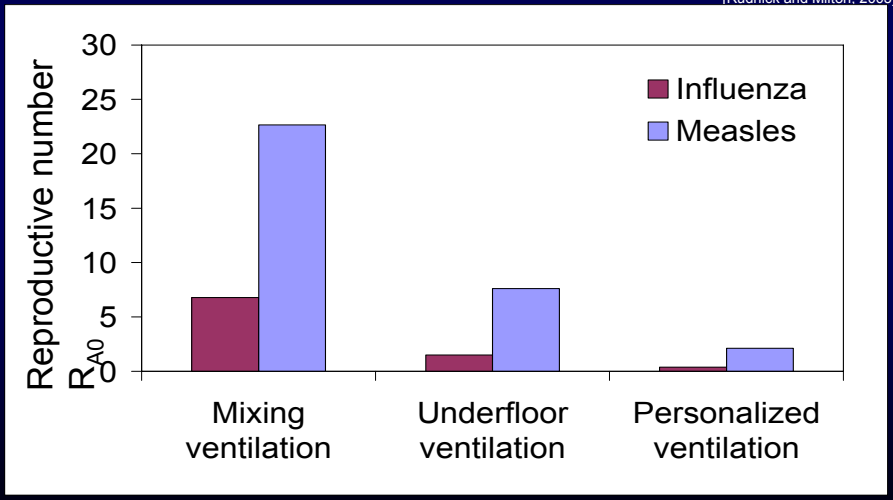


Personalized Ventilation

Protection of Occupants

R_{A0} - reproductive number of secondary infections that arise when a single infectious case is introduced into a population where everyone is susceptible

[Rudnick and Milton, 2003]



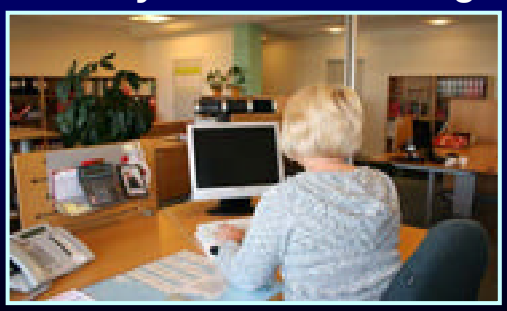
Personalized Ventilation in Practice

ICIEE, Exhausto & COWI

Development and Optimozation:

- full scale air distribution room & breathing thermal mannequin
- thermal comfort and inhaled air quality evaluated

Installation and field survey in office building

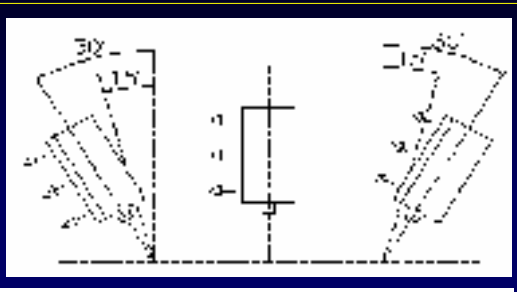


Aircraft Cabin Research: Seat Incorporated Personalized Ventilation

A. Melikov

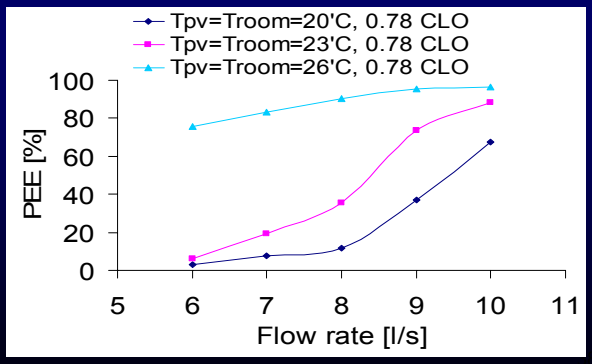
- **Inhaled air quality**
- **Protection from cross-infection**

Seat Incorporated Personalized Ventilation



Parameters:

- Flow rate
- Positioning
- Air temperature
- Size of diffusers
- Clothing insulation



Indoor environmental effects on the performance of schoolwork by children

Pawel Wargocki and David P. Wyon

Method

- Randomly selected elementary school
- No reported IEQ problems
- Mechanically ventilated
- South-facing facades
- 4th to 6th grade
- 10-12-year olds
- ~300 pupils

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Indoor environment & performance in schools

Method

- Field intervention in 6 classrooms
- Indoor air quality modified by:
  - increasing outdoor air supply rate
  - changing used bag filter with new filter
  - reducing concentration of particles in classrooms by operating electrostatic air cleaners
- Air temperature reduced by operating split cooling units
- Measurements of the performance of children

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Indoor environment & performance in schools

Method

- Tasks appropriate to children's age, developed in consulation with class teachers
  (proof-reading, subtraction, multiplication, number comparison, addition)
- No restrictions for normal daily activities
- No changes in class schedules
- Doors and windows could be opened
- No contact between researchers and children

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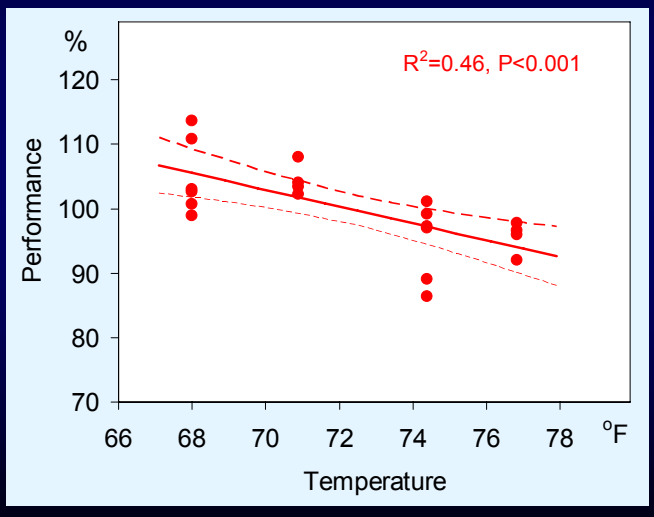
Indoor environment & performance in schools

Results: Impact of temperature



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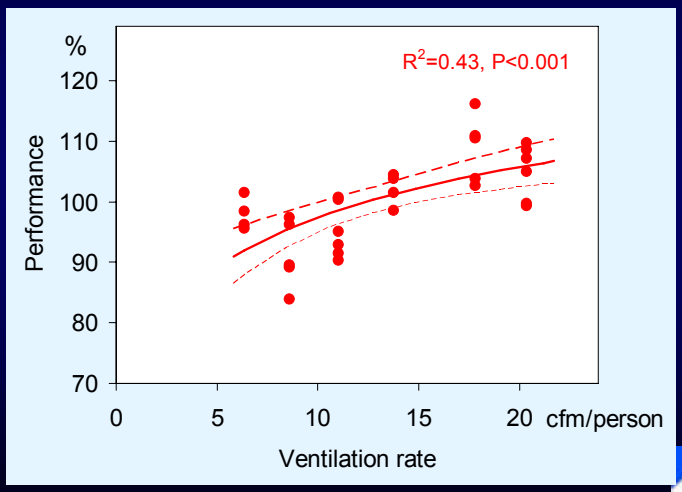
Indoor environment & performance in schools

Results: Impact of ventilation rate



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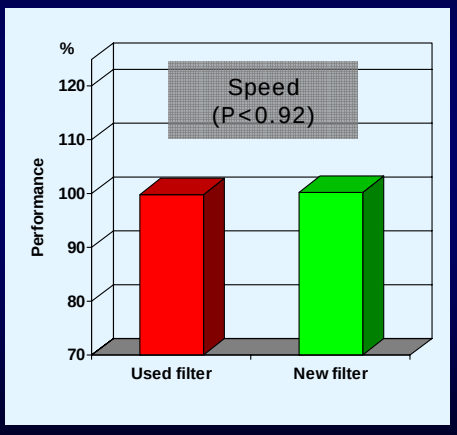
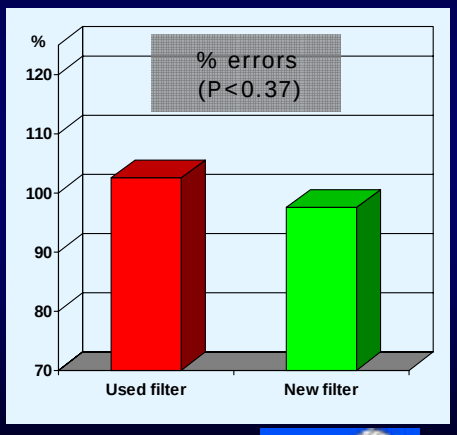
Indoor environment & performance in schools

Results: Impact of filtration





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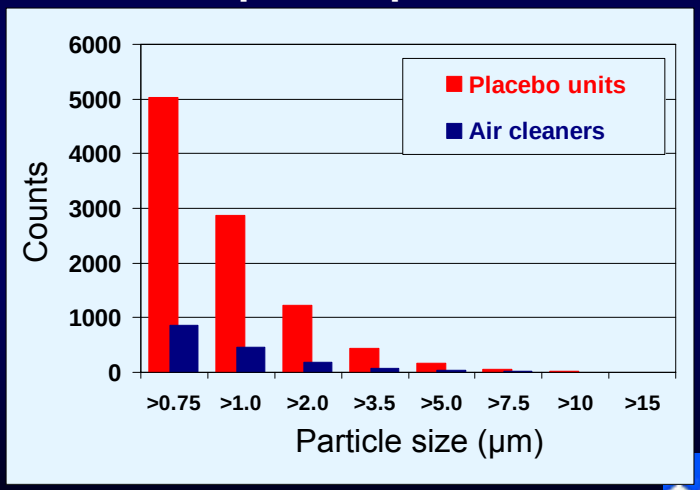
Indoor environment & performance in schools

Results: Impact of particles



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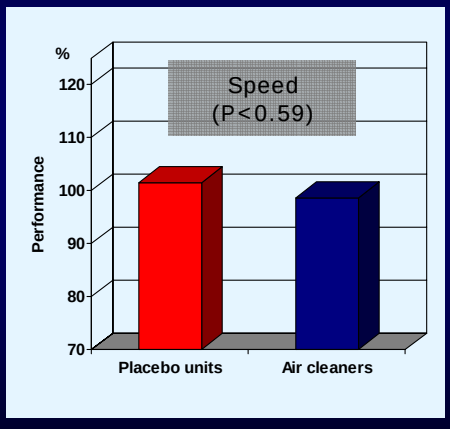
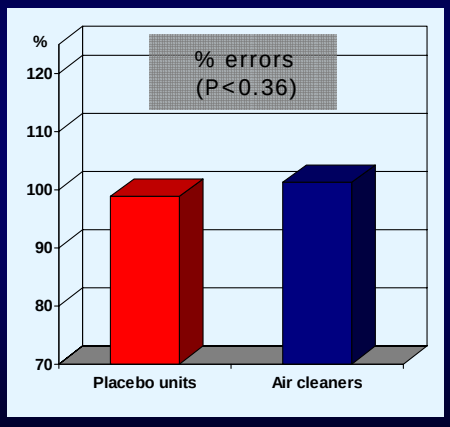
Indoor environment & performance in schools

Results: Impact of particles





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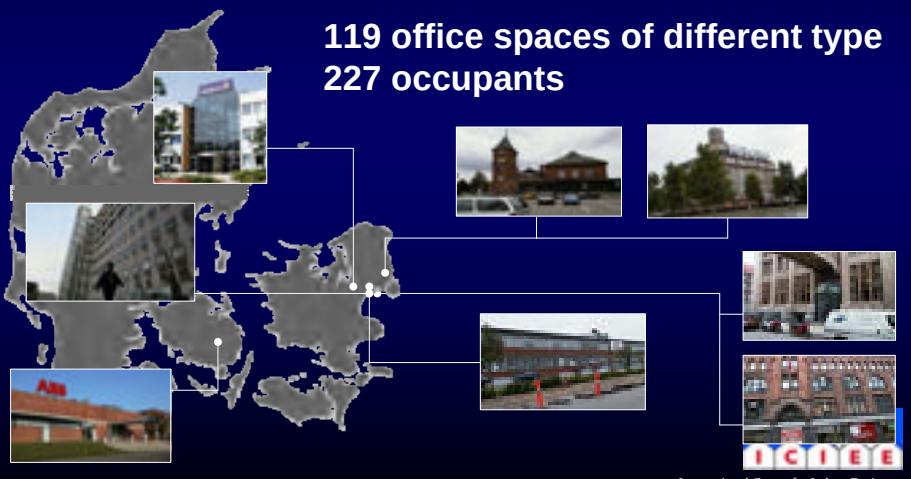
Displacement ventilation

A. Melikov, G. Pichurov, K. Naydenov,

Field Study



119 office spaces of different type
227 occupants

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Displacement ventilation – field study

Method: Questionnaire & Measurements

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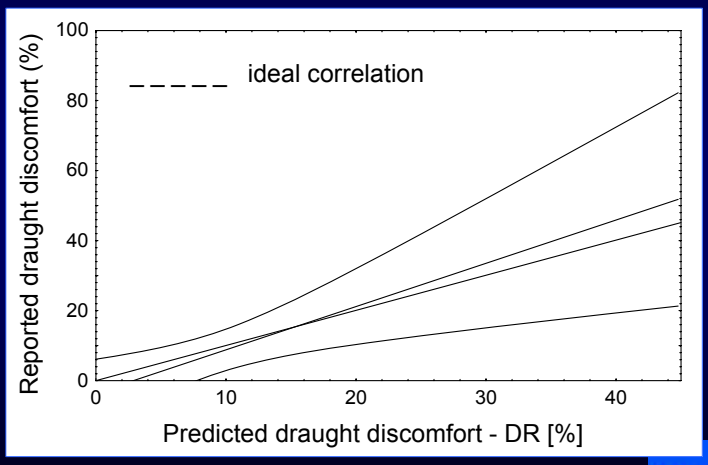
Displacement ventilation – field study

Results: Draught discomfort



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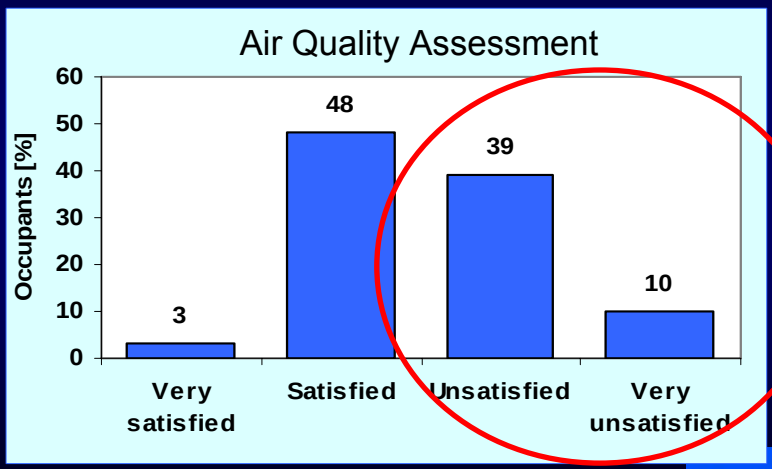
Displacement ventilation – field study

Results: Perceived Air Quality



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Displacement ventilation – field study

Results: Occupant “intervention”

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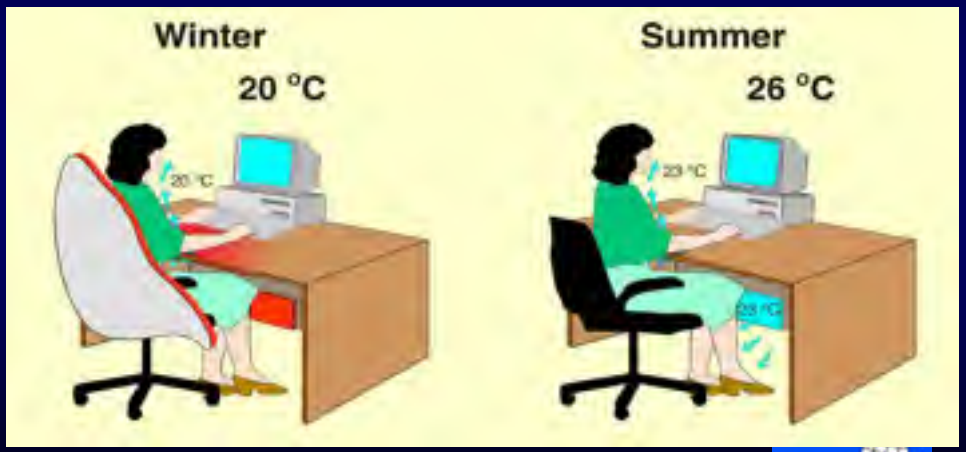
Individually controlled environment

A. Melikov & G. Knudsen



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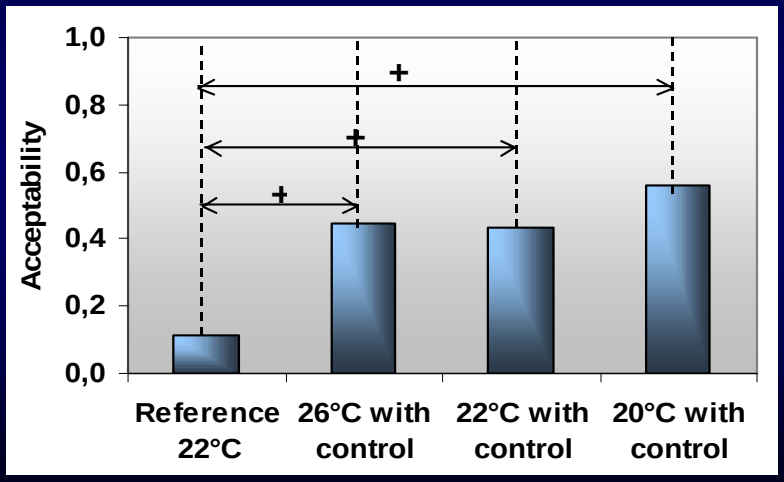
Individually controlled environment

Results: Air quality



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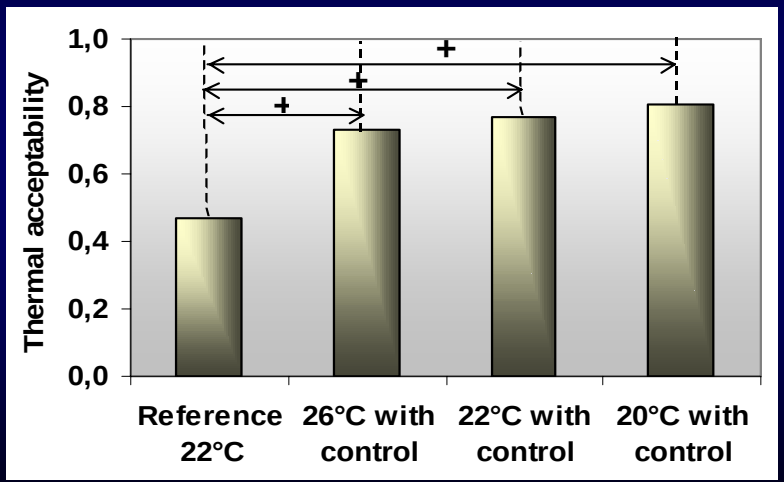
Individually controlled environment

Results: Thermal environment



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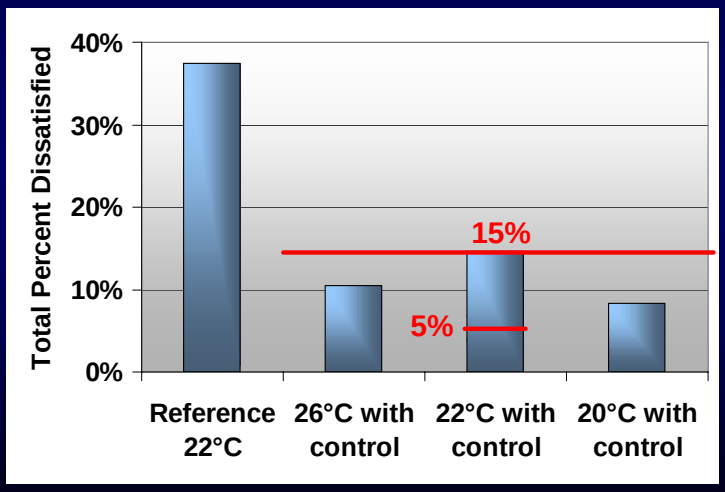
Individually controlled environment

Results: Dissatisfied subjects



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Thermal plume above a sitting person

D. Żukowska, A. Melikov, Z. Popiolek




- A cylinder and a rectangular box generate much more concentrated plumes compared to a sitting thermal manikin and do not show a realistic air movement, however, they can be used to simulate enthalpy flux and buoyancy force density.
- Chair design has significant impact on the thermal plume development above a sitting person due to changes in the ratio of convection to radiation heat losses from the body.

Aircraft Cabin Resesrach

P. Strøm-Tejsen, D. Wyon & L. Fang

Optimum balance between fresh air supply and humidity

4 different outside airflow rates → 7 - 28% RH

(7-hour exposures – 16 flights)

Conclusion:

Increasing the humidity by reducing the outside flows does not eliminate any SBS symptoms typical of the aircraft environment ... ... due to the increased level of contaminants

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Aircraft Cabin Resesrach

Thermal effects on cabin passengers under three different thermal conditions

20.6°C, 23.3°C and 26.1°C

(7-hour exposures – 12 flights)

Conclusion:

Indoor Air Quality can be significantly improved by reducing air temperature.

Changing the cabin air temperature did not reduce the intensity of most SBS symptoms.

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Occupant Responses and Energy Use in Buildings with Moderately Drifting Temperatures

J. Kolarik, J. Toftum, B. Olesen

To validate the scientific basis of the recommendations on drifting temperatures as stated in standard 55 and to evaluate the feasibility of drifting temperatures as a means of energy savings and reduced system-installed capacity

Human subject response (climate chamber and field):

Ramp rate 0 - ± 2,4 K/h, different room air temperature (17,8 – 26,8 °C), different duration and clothing

Computer simulation:

All-Air VAV system, All-Air CAV system with supply temp. control; Heavy building construction, East – West orientation

Moderately Drifting Temperatures

- 4.8 K/h (~1.1K/0.25 hr in 55) - more dissatisfied than corresponding to predictions for steady-state, increased headache, decreased well-feeling and concentration
- Allowing subjects to modify their Icl resulted in only slightly different thermal sensation and acceptability than with fixed Icl
- Subjects were more sensitive to decreasing than to increasing temperature ramps

Moderately Drifting Temperatures

- With fixed Icl, longer exposures (> 4 hrs) to temperature ramps seemed to aggravate general SBS symptoms and decrease self-assessed performance
- With adaptive Icl no effect on SBS symptoms of temperature ramps
- No consistent effect on performance of temperature ramps
- Increasing operative temperature appeared to slightly decrease the speed of addition and text typing as compared with the constant temperature condition

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